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(54) Improved method for explosive blast control

(57) An improved method of blast suppression involves forming an expanded foam barrier maintained in position by a barrier element which, in a preferred form, is inflated and maintained inflated by the foam used to form the foam barrier. Various barrier structures and methods are disclosed for suppression of the blast wave.

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1 IMPROVED METHOD FOR EXPLOSIVE BLAST CONTROL

2

3 Field of the Invention

4

5 The present invention relates to the control of
6 blasts due to bombs and explosive blast-producing devices
7 and the like and more particularly to improved methods for
8 controlling the same and especially the blast effects of
9 such devices such that the same may be detonated in place,
10 if desired, without causing significant damage to the sur-
11 rounding area.

12

13

14 Background of the Invention

15

16 Terrorist and extortion bombings have always
17 been a problem for law enforcement officials, not only on a
18 national scale but on an international scale as well. One
19 of the problems heretofore faced has been the manner of
20 disposing of a detected bomb or explosive or similar device.
21 In the more common instances, the bomb or explosive device
22 is placed in a public place or in a vehicle parked in a
23 public place. Upon detection, the problem arises as to
24 disposal of the device. In past years the procedure typi-
25 cally has been for trained bomb disposal personnel to at-
26 tempt to disarm the device on the site. There are cases,
27 however, in which the device may be quite sophisticated,

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1 More recently the potential for serious injury
2 or death of those attempting to disarm the explosive device
3 has led to the use of video camera carrying robots which
4 are brought close to the explosive device to determine its
5 size, construction or other information which may assist in
6 the safe deactivation of the device. Unfortunately, however,
7 not all law enforcement groups can afford the expense of
8 robot units and there are situations in which robots may not
9 be suitable for their intended function. For example, a
10 robot may not be able to disarm a bomb in a briefcase left
11 in the open. In such a case, the use of a robot normally
12 involves picking up the device and carrying it to a disposal
13 vehicle in which the device is transported to a remote bomb
14 disposal site. Should the device detonate during transport
15 by the robot to the disposal vehicle, there is a potential
16 for significant injury to those in the area as well as sig-
17 nificant property damage in the immediate area.

18 Perhaps the largest single cause of bodily injury
19 in detected explosive devices comes from blasts which take
20 place as the law enforcement officials first on the scene
21 attempt to disarm the bomb in order to protect the public and
22 the surrounding property. There are instances in which the
23 nature of the explosive device is such that it is not readily
24 capable of being deactivated at the site, but where it is
25 attempted to disarm the device in order to protect the sur-
26 rounding property. In some cases, the procedure is to detonate
27 the device on site by the use of a smaller explosive device

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1 immediate area. In other cases, the smaller device is
2 used in an attempt to deactivate the main explosive de-
3 vice, by destroying wires or disabling the detonation
4 mechanism. The latter procedure, however, may result in
5 detonation of the main device and a more powerful blast.
6 Even if successful, the detonation of the smaller charge
7 may cause damage to valuable property in the immediate
8 vicinity. Timer controlled or remote controlled devices
9 add still another complexity to deactivation of the explo-
10 sive device, that is, the need to act both quickly and with
11 precision.

12 Typically, the damage done by the explosion comes
13 from two sources, the first being the compression wave of the
14 blast and the second being the fireball which immediately
15 follows the blast. --The compression wave is usually a high
16 amplitude, short duration compressive wave which moves ra-
17 dially outwardly in all directions from the source. The
18 strength of the wave and its duration are a function of the
19 power and amount of the explosives used in the device. The
20 fireball is a result of combustion of the combustable materials
21 in the immediate region of the blast and is almost immediate
22 with the compressive wave. Since the fireball consumes the
23 combustibles in the region of the device, the effect is a
24 reduction in the pressure behind the compressive wave with the
25 net effect that there is a high pressure overpressure by the
26 compression wave followed almost immediately by a reduced
27 pressure front. The fireball also operates to ignite the com-

1 compressive wave may cause significant structural damage to
2 the vehicle, including rupture of the fuel tank, if the ex-
3 plosive is powerful enough. The fireball may ignite the
4 interior of the vehicle if there is combustible material
5 present and may cause either a secondary explosion as the
6 fuel detonates or a severe fire as the fuel ignites. The
7 result is that the region around the vehicle is traversed
8 by debris blown by the blast, followed by a secondary explo-
9 sion or intense fire.

10 For relatively small devices, such as letter bombs
11 and briefcase bombs, it may be possible to use blast blankets
12 placed over the device to inhibit the effects of the blast
13 as the device is detonated on site. The difficulty with
14 bomb blankets is that they are quite heavy, usually formed
15 of flexible closely woven steel mesh and not easily trans-
16 portable to the needed site. The weight of the blast blankets
17 may be such as to require the use of a crane. Moreover,
18 blast blankets are not usually available quickly. In the
19 case of bombs placed in vehicles, the number of blast blankets
20 needed to cover the entire vehicle may be more than is imme-
21 diately available, even if there is available equipment to
22 position the blanket.

23 It is also known that explosive materials are used
24 in building clearance programs in which relatively large
25 structures, sometimes in populated areas, are felled by explo-
26 sive charges placed at strategic locations in the main support
27 structure and usually detonated in a timed sequence. While

1 problems do arise. Typically, the charges are set and when
2 detonated, the structure collapses as planned, but sometimes
3 there is a substantial amount of window breakage in the
4 structures in the surrounding area. Normally, the explo-
5 sives used in these types of operations tend not to produce
6 a fireball, but do produce a significant compression wave.
7 Further, since the charges are usually set at ground level,
8 there may be significant window damage at street level.

9 As is apparent, it would be desirable to provide
10 a system which absorbs the compression wave so as to reduce
11 the structural and bodily injury caused by the blast over-
12 pressure while significantly reducing the fireball so as to
13 reduce the damage caused by the combustion of ignitable or
14 explosive material in the immediate vicinity of the blast.
15 Particularly advantageous would be a system which is readily
16 mobile, easy to use, effective for the purpose intended and
17 which suppresses the fireball as well as the effect of the
18 compressive wave..

19 It is known in the prior art to use foams in
20 fighting fires. Typically such foams are formed from water-
21 soluble surfactants of the perfluorocarbon type which may be
22 dispensed from a variety of different types of equipment,
23 all well known in the art. One such typical material is
24 known in the art as AFFF, see United States Patents 3,258,423;
25 3,562,156 and 3,772,195, for example. Generically these
26 materials are also known as FCS and HCS materials, e.g.,
27 fluorocarbon surfactants and hydrocarbon surfactants. Varia-
28 tions include those AFFF compositions which contain

1 see for example United States Patents 4,090,967 and 4,014,926.
2 These foam producing materials are known to produce high-
3 expansion foams which are known to spread over the surface
4 in order to suppress vaporization of gasoline, which is
5 the principal reason these materials were developed. Other
6 patents which disclose similar materials are United States
7 Patent 4,090,967, United Kingdom Patents 1,230,980 of 1971
8 and 1,126,027 of 1968, and Canadian Patent 842,252, for
9 example.

10 Foams from the above and other equivalent materials
11 tend to be of small envelope or bubble size and flowable, the
12 latter being one of the desirable qualities for use in fight-
13 ing fires. Moreover, the foams may be formed relatively
14 easily at the site of application by any number of different
15 devices, all well known in the art. Portable units of various
16 sizes as well as truck mounted units are commercially avail-
17 able for forming and dispensing various amounts of foamed
18 material. For example, units are available which dispense
19 from 2,000 to 15,000 or more cubic feet of foam per minute.
20 Dispensing units include water reaction motors, electrically
21 powered units, turbine units, compressed gas driven units
22 and the like. Some of the dispensing equipment includes a
23 tubular member which may be from two feet to ten feet in
24 diameter, connected to the foam generator, and used to con-
25 trol the direction of foam discharge. The foam is discharged
26 from the open end of the tubular member remote from the foam
27 generator. The result is that an enormous amount of foam
28 can be quickly dispensed from a relatively small unit in a

1 and foaming agent. Since the foam includes a surfactant,
2 it tends to flow easily and spread quickly over the con-
3 tact surfaces which it readily wets. Such foams may also
4 be dispensed from high velocity nozzles and projected a
5 relatively long distance and with sufficient accuracy to
6 reach a designated target area.

7 Typically, the foams above described are some-
8 times referred to as expanded foams, having an expansion
9 ratio of 50 to 1 to 1000 to 1. These types of foams do
10 not have sufficient strength to remain in a three-dimen-
11 sional shape, for example, a mound, for any significant
12 length of time. Where the foam is dispensed from a tubular
13 member, customarily referred to as a chute, the chute may
14 be of a length of one hundred feet or more, with the foam
15 being dispensed from the open end of the chute remote from
16 the generator. Generators are known which have an output
17 or discharge opening which may vary from one square foot
18 to as much as twenty-five or more square feet.

19 The foams described, dispensed by known equipment
20 and techniques, tend to have a relatively long life since
21 collapse of the foam is due principally to evaporation of
22 the water component of the foam. Thus in the absence of
23 heat or flame, the foam tends to remain fairly stable for
24 a relatively long period. However, it is also true that the
25 foam tends to spread laterally rather quickly since this is
26 one of the desirable features in its use as a fire-fighting
27 material.

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1 Even though known, there appears to have been little prac-
2 tical use of foams as a blast suppression medium apparently
3 because of the inability to deliver the foam to the desired
4 location and to maintain the foam in the immediate region
5 of the explosive device. In other words, there does not
6 exist in the prior art a methodology for containing the foam
7 in the desired location, nor was it apparently recognized
8 that the key to the successful use of foams as a blast sup-
9 pression medium was dependent upon confining the foam. As
10 near as can be determined, little use has been made in open
11 areas, such as streets, large rooms and the like, of foams
12 as a blast suppressor because it may not have been recognized
13 that the effectiveness of the foam as a blast suppressor
14 could be significantly increased by confining the foam.

1 Summary of the Invention

2

3 In accordance with the present invention, an
4 improved blast suppression method is provided through the
5 use of foams heretofore used in fire fighting and wherein
6 the formed foam is confined in such a way as to control the
7 continued propagation of the blast wave, thereby absorbing
8 the compression wave in all radial directions or selectively
9 absorbing the blast wave so that its continued propagation
10 in any given direction is suppressed.

11 The principal advantage of the present invention
12 is that the explosive device may be detonated on site with a
13 marked reduction in the destructive effect of the compression
14 wave, and virtually complete confinement of the fireball (if
15 the explosive is the type that tends to generate one) and
16 any subsequent fire or secondary explosion. Since many
17 terrorist and extortion bombs are placed in open areas or in
18 large rooms, or in the case of building demolition, involves
19 the use and detonation of high explosives in open areas,
20 an important aspect of the method of the present invention
21 relates to the confinement of the foam such that a barrier
22 may be provided, relatively easily and effectively, to con-
23 tain the compressive wave so that continued propagation in
24 undesired directions is either controlled or substantially
25 eliminated. Various methods may be used to create the
26 barrier, which may be of various shapes and sizes depending
27 upon the nature of the control desired.

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1 device (if in a vehicle, fully surrounding the vehicle),
2 and of a vertical height sufficient to contain a foam
3 barrier which fully encloses the device in all directions
4 above ground. The actual dimensions of the foam barrier,
5 in this case, are preferably such that there is sufficient
6 volume of foam maintained in place to suppress the com-
7 pression wave which emanates from the blast. The rate of
8 decreased of the intensity of the overpressure of the
9 compression wave for various amounts and types of explosives
10 is known in the art, and thus the dimension of the con-
11 tainment structure and the foam barrier within the contain-
12 ment structure may be ascertained to bring about the desired
13 degree of suppression. For example, the suppression effect
14 of the foam is related to its expansion ratio; the higher
15 the expansion ratio, the less dense the foam, and thus
16 more radial thickness is needed for a given weight of explo-
17 sive. More particularly, the radial dimension of the foam,
18 as measured radially outwardly in all directions above
19 the ground from the explosive device is related to K times
20 the weight of C4 plastic explosive to the $1/3$ power. K is
21 a constant which varies with the expansion ratio of the
22 foam. The higher the expansion ratio of the foam, the
23 greater the amount of foam which is needed. The weight of
24 C4 is normally approximated based on the type and weight
25 of the explosive and is expressed as an approximate equi-
26 valent weight of C4. For example, 5.3 ounces of C4 is the
27 equivalent of about one stick of dynamite.

28 To next the size geometry and placement of

1 are a function of the type of protection needed. For
2 example, at overpressures of 4 or more psi, as measured
3 at the structure, an explosive blast may produce serious
4 structural damage depending upon the nature of the con-
5 struction of the structure, e.g., wood versus reinforced
6 concrete, for example. At overpressures of 1/2 to 1 psi,
7 as measured at the structure, the result is usually win-
8 dow and glass breakage. In building demolition, which
9 usually involves precisely placed shaped charges of known
10 explosives and of known weights and power, the confinement
11 barrier and the foam dimensions may be configured to pre-
12 vent propagation of overpressures which cause glass break-
13 age. In the case of bombs, the situation may be entirely
14 different and the prevention of structural damage may be
15 all that is desired, or all that can be achieved, because
16 of the nature of the device and its location.

17 One of the significant advantages of the pre-
18 sent invention is that it may be practiced with equipment
19 and materials now generally available, for example, from
20 Rockwood Systems Corporation.

21 In a preferred form of the present invention,
22 the confinement barrier is formed by one or more chutes
23 now used to dispense fire fighting foam, wherein the
24 chutes are modified such that the delivery end is sealed.
25 The chute may, for example, be lightweight plastic or
26 fabric or any other suitable material capable of acting
27 as a conduit for the foam. One or more apertures are

1 to dispense the foam in a given, controlled direction once
2 the chute is properly positioned, as will be described.
3 In one form, the chute is fully collapsible, i.e., it is
4 not self-supporting, for ease of handling, storage and
5 transporting. Other chute structures may be used, as will
6 be described. At the site, the chute is positioned a dis-
7 tance from the bomb location and preferably in an arrange-
8 ment which fully surrounds the device to be detonated. For
9 example, the chute may form a circle with the bomb located
10 at the center of the circle. The chute is oriented such
11 that once inflated as will be described, the openings are
12 pointed in the direction of the device. One or more chutes
13 or lengths of chute may be used, as needed to form the
14 circle.

15 One or more foam generators may be attached to
16 the chutes and started, filling the chutes with foam and
17 expanding the chutes to form a foam-filled containment
18 barrier. This procedure, in effect, erects a barrier which
19 fully surrounds the device and extends vertically above
20 the ground. The vertical height of the barrier may vary,
21 as will be described. Once the barrier is erected, the
22 foam from the generator or generators exits through the
23 directional openings in the chute toward the device. The
24 generator or generators are kept on until the entire region
25 within the foam-filled barrier is filled with foam to a
26 height at least equal to the vertical height of the foam-
27 filled chute barrier. During the filling of the chutes,

1 separates and collects at the bottom of the chute, acting
2 as a weight to keep the chute in place.

3 After the entire volume within the foam-filled
4 containment barrier is filled with foam, the area around
5 the outside of the barrier may be cleared of people and the
6 device detonated. The generators may be kept on or turned
7 off depending upon the amount of foam needed. Since the
8 foam is made up of a multiplicity of small bubbles, con-
9 tained by the barrier system, an effective blast suppression
10 enclosure is formed of compressible material which absorbs
11 the compression wave or a substantial portion of the com-
12 pression wave. Clean up of the area is relatively simple
13 and involves hosing the area with water to disperse or dis-
14 solve the foam.

15 Further details of this invention and a fuller
16 understanding of the various ways in which it may be prac-
17 ticed may be better understood with reference to the follow-
18 ing disclosure in which various forms of the invention are
19 disclosed.

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1 Detailed Description of the Invention

2
3 In accordance with a preferred form of the in-
4 vention, high-expansion foam may be used for several different,
5 but beneficial, purposes in the suppression of explosive
6 blasts. One purpose is to absorb the blast wave, provided
7 a suitable barrier is provided to contain the foam in a
8 defined area and in a controlled shape. As will be described,
9 the barrier may be provided in several different ways. Ano-
10 ther purpose is to extinguish the fireball, if one is
11 formed, thus reducing secondary fires and secondary explo-
12 sions, if the conditions are right for the latter to occur.
13 Again, effective fireball and secondary fire and explosion
14 control depend upon the formation of an effective barrier.
15 Still another purpose of the foam is to assist in the forma-
16 tion of a physical barrier which, in turn, forms a containment
17 structure for the foam which surrounds the device and which
18 forms the principal medium for blast suppression.

19 The foam itself is a mass of uniform bubbles made
20 from a water-detergent solution in which one part of the
21 water-detergent solution may be expanded to from 50 to 1000
22 parts of expanded foam. The water-detergent solution may be
23 of any of the materials previously mentioned and generally
24 involves between 1% and 6% or more of detergent. The con-
25 centrate may be, for example, a synthetic base foam concen-
26 trate reinforced with protein additives and is used in the
27 ratio of 1 to 3 parts by volume for each 100 parts of water
28 by volume to form the foam. Other materials and other ratios

1 is one known as JET-X, available from Rockwood Systems
2 Corporation. Such a material, at an expansion of 600 to 1
3 contains about 75 gallons of water per 6,000 cubic feet of
4 foam. These foams are also considered to be benign in the
5 sense that full immersion for 60 minutes or so causes no
6 harmful effects. Yet, care should be taken since there is
7 a total loss of orientation when immersed in foam due to
8 the inability to see or hear.

9 Foam generators are available which are capable
10 of producing between 1,250 and 22,000 cubic feet of foam
11 per minute. The expansion ratios of the foams used in such
12 generators may vary from 135 to 1 to 1000 to 1, using water
13 at a rate of between 37 gallons per minute at a pressure of
14 75 psi to as high as 165 gallons per minute at a pressure
15 of about 100 psi. The weight of the generators may be as
16 light as 10 pounds to as heavy as 350 pounds or more, and
17 may be portable, trailer mounted or truck mounted. These
18 commercially available units may also be helicopter trans-
19 ported. Various types of generators are available such as
20 water reaction powered units, air aspirated units and the
21 like. The generators generally require air for the forma-
22 tion of foam and operate best with fresh air.
23

24 One aspect of the foam and generation of foam is
25 the fact that it tends to flow. Thus, an important aspect
26 of this invention is the control of the foam, to prevent flow
27 usually relied upon in fire fighting applications, and in
contrast to such applications, to control the foam so as

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1 confined within a defined location to a vertical height
2 desired for blast suppression.

3 In a preferred form of the invention, the foam
4 itself is used to construct the foam containment barrier
5 at the desired location. To this end, a chute member is
6 used and preferably arranged so as to surround the explosive
7 device to be detonated. "Explosive device" as used herein
8 may in fact be more than one explosive charge, as for
9 example in building demolition in which a series of charges
10 are set off in a continuous controlled sequence, as will be
11 described. In the case of an explosive device such as a
12 bomb, the chute is preferably arranged in a circular pattern
13 around the device, but spaced radially therefrom. It is
14 understood, however, that there may be circumstances in
15 which the containment barrier may be of different shapes and
16 wherein the barrier may not itself extend completely around
17 the device. For example, where a bomb is placed near a
18 building or other structure, such as a wall or dense bushes,
19 the building or other structure may in fact form part of
20 the barrier, with the chute forming the remaining portion of
21 the barrier. The chute barrier may be of various cross-
22 sectional shapes such as circular, square, rectangular, tri-
23 angular, or the like. The chute may be fabricated of a
24 variety of different materials such as plastic, nylon mesh or
25 reinforced plastics, each of which is preferably foldable
26 and relatively lightweight and flexible for easy storage,
27 transport, handling and the like. In this form of the
28 method of the present invention, the chute is not self-

1 partly collapsed shape. The chute may be fabricated such that
2 as laid out on the ground, for example, it has an
3 arcuate shape, e.g., it forms part of a circle.

4 The chute may vary in length from 25 to 100 feet
5 or more and may be of a vertical height, when expanded, of
6 25 feet or more. A triangular shape has the advantage of
7 a decreasing cross section in the vertical direction and
8 thus the weight of foam gradually decreases in the vertical
9 direction. This, however, is a more difficult and more
10 expensive shape to manufacture, especially if made of plastic
11 material. Regardless of the cross-sectional shape of the
12 chute, it is preferred that one end be sealed closed and
13 that there be at least one opening formed in a sidewall
14 and so arranged that as the chute is laid out or unfolded
15 during use, as will be described, the opening is pointed in
16 the general direction of the device and the region to be
17 foamed. This opening is a foam discharge opening and the
18 chute may have several such openings along its length, de-
19 pending upon the length of the chute and its diameter. If
20 there is more than one opening, they may be located to direct
21 foam at different elevational angles relative to ground
22 level. The chutes used to form the barrier need not be of
23 the same shapes or vertical heights. For example, if a
24 bomb is located on a relatively steep street, it may be
25 desirable to use a barrier on the lower side of the street.
26 which is of a vertical height greater than the barrier on
27 the high side of the street since the high side of the
28 street above the bomb may absorb some of the blast, and the
29 angle of the street acts to direct the blast more in the direc-
30 tion of the lower side of the street. Under these circumstances,

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1 difficult to contain the foam on the low side of the street
2 because of the tendency of the foam to flow downhill.

3 The barrier members may be positioned in place
4 relative to the device in any number of different ways,
5 depending upon the particular situation. If the danger is
6 severe robots may be used to position the deflated bar-
7 riers. Lanyards attached to the deflated barrier chutes
8 may be projected across the area and used to position the
9 chutes. The chutes may be placed by helicopters. Regard-
10 less of the technique used to position the chutes, they
11 should be located in such a manner as to provide the desired
12 suppression when expanded and when the area is filled with
13 foam. It is possible for example to position one or more
14 foam generators at various points with the chutes, in rolled
15 up form, attached to the foam generator. As foam is generated
16 and propelled down the chute, it unrolls and fills with foam,
17 with the foam being dispensed toward the device through the
18 foam exit apertures. The chutes may be laid out on the sur-
19 face in the shape desired and at the proper distance from the
20 device. Thereafter, the foam generators may be attached and
21 the chutes inflated with foam, the foam again being directed
22 towards the device through the exit apertures.

23 It is also possible to use foam generators of dif-
24 ferent outputs for different purposes. For example, the chute
25 barriers may be filled and maintained filled with generators
26 of moderate capacity, while the region to be foamed is filled
27 by a generator of greater output. In this case, the foam may
28 be dispensed by a large duct arranged to dispense the foam

1 filled, the chute barrier is moved back into position to
2 complete the containment barrier. Once the containment
3 barrier, kept inflated by foam, is in place and the region
4 surrounded by the barrier is filled with foam, the device may
5 be detonated. The compression wave is absorbed by the foam
6 on the inside of the barrier, which acts as an attenuator
7 to suppress the wave such that the overpressures travelling
8 beyond the foamed enclosure are significantly reduced. It
9 is, of course, preferred in accordance with the present in-
10 vention to attenuate the compression wave to the extent that
11 the overpressures at the structures surrounding the site are
12 kept below 1/2 psi.

13 In some instances, due to the size and/or poten-
14 tial power of the explosive device, it is not reasonably
15 possible to achieve such marked reduction in the overpressure
16 in all directions from the site of the device. In such in-
17 stances, the best course of action is to attempt to attenuate
18 the blast wave in all directions along the ground and for a
19 reasonable vertical distance above ground, and at the same
20 time focus the shock wave in a generally upward or vertical
21 direction. This is possible in accordance with the present
22 invention by spacing the chute barriers at the appropriate
23 radial distance from the device and of the proper height, as
24 described. The enclosure is filled with foam, as previously
25 described. Even though the depth of the foam may not be
26 sufficient to substantially attenuate the generated shock
27 wave in a vertical direction, there may be substantially
--

1 since the dimension of the foam is sufficient in a lateral
2 dimension to achieve substantial lateral attenuation, but
3 insufficient to achieve the same effect vertically above
4 the device, there is a non-uniform attenuation of the shock
5 wave. Thus, there is maximum attenuation at the outer peri-
6 pheral edge of the foam in a lateral plane at the level below
7 the foam, which attenuation tends to decrease progressively
8 towards the point at the top of the foam immediately above
9 the device. The reduction in attenuation, however, is non-
10 linear, with the result that the blast wave is focussed
11 upwardly in a generally vertical direction with markedly
12 reduced vertical component. In certain cases this may be
13 an entirely acceptable situation, especially where a device
14 is in an open area surrounded by tall buildings with large
15 glass windows at ground level. Depending upon the depth of
16 foam which the barrier contains, overpressures of less than
17 1/2 psi at ground level may be quite acceptable, even though
18 the overpressures may gradually increase vertically at the
19 structure interface for some limited vertical distance. For
20 example, if the barrier and foam height at the periphery of
21 the barrier is 25 feet, overpressures of the structure inter-
22 face up to a vertical distance of 25 feet may be less than
23 1/2 psi, even though the overpressure for a region above 25
24 feet may increase somewhat. Since the distance from the bomb
25 position as measured vertically to the structure interface
26 increases as a function of the hypotenuse of a right triangle,
27 the linear distance to the top of the foam blanket may de-
28 crease but the distance from the bomb site to the structure

1 intensity as it travels in air, though not as great a
2 reduction as achieved by foam suppression, is nonetheless
3 reduced, even though the wave travels through a lesser
4 dimension of foam in the region of the foam blanket imme-
5 diately above the device.

6 Thus, there is maximum attenuation at ground
7 level (zero elevation) in all azimuthal directions for a
8 given depth of foam. At 90 degrees elevation, there is
9 minimal attenuation because of the smaller dimension of the
10 foam blanket. At a given elevation, the attenuation is
11 the same in all azimuth directions, assuming the same linear
12 dimension of foam is present. The total effect is that the
13 blast wave is, in effect, focussed vertically where little
14 damage may occur, provided there are no structures verti-
15 cally above the device.

16 In accordance with the present invention, con-
17 tainment barriers may be configured specifically to focus
18 the blast wave in a vertical direction. For example, an
19 inner barrier may be formed of one vertical dimension with
20 an outer barrier of a greater vertical dimension spaced from
21 the inner barrier, e.g., the inner barrier is 10 feet high
22 while the outer barrier is 25 feet high. The entire region
23 within the inner and outer barriers is filled with the foam.
24 The result is a foam contained region in which the device is
25 covered with foam to one height, extending laterally for a
26 given radial distance from the device. The foam barrier
27 from the inner containment device to the outer containment

1 device, the site of the device, the available generators
2 and the circumstances are such that it is not possible to
3 erect a foam barrier of the optimum full height.

4 As is apparent to those knowledgable in explosive
5 devices, the foam barrier may be constructed in a
6 number of various ways and in a number of various config-
7urations in order to achieve significant attenuation and
8 suppression of the blast wave, as may be needed by the
9 particular circumstances. In accordance with the present
10 invention, and as described, the essential feature is to
11 provide a foam barrier which is contained in order to
12 suppress the blast wave by the foam, which to be effective
13 for its purpose must be fixed in position to act as the
14 effective suppression medium which it forms.

15 By way of example, any number of different
16 devices may be used to construct the physical barrier for
17 the foam. For example, it is possible to erect foam bar-
18 riers from various forms of sheet material supported by
19 any number of different means. For example, overlapping
20 plastic sheets may be hung from the windows of structures
21 to be protected so as to form a barrier curtain. The foam
22 may then be dispensed from a high capacity generator capable
23 of generating foam at the rate of 22,000 cubic feet per
24 minute. Buildings and automobiles or vehicles may be used
25 as the barrier or a portion thereof since the nature of the
26 foam is such that it tends to build vertically whenever it
27 encounters any form of obstruction to lateral flow. The

1 in the absence of fire or heat, tends to be stable for a
2 period of time sufficient to provide the suppression medium
3 to absorb the blast wave.

4 According to the present invention, the contain-
5 ment barrier may be formed of plastic or other material sup-
6 ported in a vertical position for the desired height. It
7 may, for example, be formed by sheets supported from verti-
8 cally arranged support elements, such as poles or vertically
9 supported guide stringers. Chutes, however, are preferred be-
10 cause water from the foam tends to separate from the foam
11 and settle at the base of the chute, acting as a weight. The
12 barrier may be fixed in place to the supporting surface in
13 order to prevent movement, if necessary. Self-supporting
14 hollow barrier elements may be used, especially where the
15 dimensions of the barrier member are such that the foam lacks
16 sufficient strength to keep the barrier inflated or in place.
17 Barrier elements of various different types may be used to
18 form a containment barrier structure. For example, plastic
19 sheet strung from buildings may be used to form a portion of
20 the barrier structure, while chute barrier elements or fence
21 type elements may constitute the remainder or a portion of
22 the remainder of the barrier structure. A plurality of bar-
23 rier closures of the same or different heights may be used.
24 Thus, by way of example, the inner barrier structure may be of
25 a greater height than the outer barrier, in which case the
26 outer barrier not only forms a suppression medium, but also
27 forms a lateral support element for the inner barrier. Vir-
28 tually any form of structure may be used as a barrier since

1 the nature of the foam is such that it tends to build up
2 when it encounters an obstruction to lateral flow.

3 As stated previously, another advantage of
4 the use of confined foam as a blast suppression medium is
5 the fact that the fireball is contained, thus containing
6 secondary fires and tending to inhibit secondary explosions.

7 A series of tests was performed to establish the
8 ability of the contained foam to act as a suppression medium.

9 In one series, 5.3 ounces of C4 was placed in a four-door
10 sedan and detonated. The doors blew open, as did the trunk
11 and the hood, while the top was severely crowned upwardly.
12 The windshield was blown forward about 200 feet and a large
13 fireball was formed upon detonation, causing an interior
14 fire which consumed the vehicle and spread to the adjacent
15 area. The same style of vehicle, a four-door sedan, had the
16 same amount and type of explosive positioned in approximately
17 the same location in the vehicle. It was then completely
18 filled with foam and the C4 charge was detonated. In this
19 case there was no buckling of the hood, top or trunk door;
20 the doors remained attached and there was no window damage
21 and the windshield remained in place. Furthermore, the fire-
22 ball was completely contained such that there was no interior
23 fire and no secondary fire.

24 The test was repeated, again using a four-door
25 sedan with 10.6 ounces of C4 positioned as in the previous
26 two tests. The vehicle was filled with foam and the device
27 detonated. In this case the damage amounted to a blow out

1 deformed. It is true that in each case there was interior
2 blast damage, but the blast, in the foam filled vehicles,
3 was contained.

4 In another series of tests, two four-door sedans
5 with 20-gallon fuel tanks each had five gallons of gasoline
6 placed in the tank. A charge of 5.3 ounces of C4 was posi-
7 tioned under the gas tank of each vehicle. One vehicle was
8 surrounded by a barrier about five feet high and the space
9 between the vehicle and the barrier filled with foam. The
10 second vehicle was not surrounded by a barrier. Neither car
11 was filled with foam. In the case of the barrier contained
12 vehicle, no significant outer structural damage took place.
13 In the non-barrier test, the trunk door blew upwardly. In
14 neither case was there any effect from the fireball since the
15 foam was of a sufficient height to cover the charge, but in
16 the barrier test the car was completely covered by foam.

17 In still another series of tests, 5.3 ounces of
18 C4 was placed at ground level within a barrier of five feet
19 in diameter and five feet high. The barrier was filled with
20 foam and the charge detonated. There was no damage to the
21 barrier structure and the blast was fully contained. In a
22 companion test, the same weight of C4 was suspended in a
23 trash can, the latter being positioned inside a barrier five
24 feet in diameter. In this case the peripheral area around
25 the can was filled with foam such that there was a non-foamed
26 region between the charge and the can wall. Upon detonation,
27 the barrier was blown off its support structure. In these

1 plastic sheet being about five feet high. This test demon-
2 strated the desirability of having the foam as close to the
3 device as possible for suppression purposes, and preferably
4 in contact with the device.

5 In still another test, to establish that a barrier
6 system could be used to direct the direction of the blast
7 wave, two concentric barriers were arranged with an open space
8 inside the inner barrier. A charge of 5.3 ounces of C4 was
9 positioned at ground level in the center of the inner barrier
10 and the annulus between the two barriers was filled with foam
11 to a height of about five feet. When detonated, the blast
12 effect was vertically upwardly, with no damage to the barrier
13 structure. Ground debris was blown upwardly in a vertical
14 direction and landed, in some instances, outside the outer
15 region beyond the periphery of the outer barrier.

16 In the case of building demolition, the present
17 invention may be used to prevent damage to the surrounding
18 structures. Usually in building demolition, shaped charges
19 are used, and set off in a timed sequence, such that the entire
20 structure is felled with what amounts to one sequential but
21 unitary blast. The charges are normally set in such a way
22 that the debris falls inwardly. There are, however, variations.
23 The problem is that the charges located along the outer peri-
24 phery and those inwardly, even though shaped charges and located
25 to sever major structural reinforced columns, there remains
26 a blast vector which is generally horizontal. Since these
27 charges are set at ground level, there may be some ground

1 used to reduce such damage by providing a foam curtain
2 around the outer periphery of the structure to be felled by
3 explosives. Unlike terrorist or extortion bombs, which are
4 intended to destroy property and life, the felling of struc-
5 tures by explosive demolition is controlled and known. Thus
6 it is somewhat easier to fabricate a barrier structure which
7 is effective for the intended purpose, especially since the
8 size, strength, location and intended effect of the charges
9 are known.

10 Accordingly, containment barriers may be used to
11 suppress the blast effects known with some precision. Blast
12 curtains may easily be fabricated, using chutes or blast
13 curtains, located around the outer periphery of the struc-
14 ture and of a height sufficient to reduce substantially the
15 potential for glass shattering. In a typical system, a double
16 barrier system, as described, may be used around the periphery
17 of the structure to be felled in order to suppress the lateral
18 blast effects generated around the structure during demolition.
19 Chutes may be used as well as spaced curtains, foam filled,
20 not only to suppress the blast effects, but also to reduce
21 the dust formed during felling. Any of the systems, as des-
22 cribed, may be used. From the nature of the operation, how-
23 ever, one alternative is to suspend curtains from the struc-
24 ture to be felled, or to position the curtains from an inde-
25 pendent support system, with the region between the curtains
26 filled with foam. Depending upon the particular circum-
27 stances, a wide variety of barrier systems may be used. It

1 It will become apparent from the foregoing des-
2 cription that a much improved method has been provided for
3 the attenuation and suppression of blast effects in a
4 significant number of circumstances. To those skilled in
5 the art of foams and to those skilled in the art of explo-
6 sives, it will become apparent that various modifications
7 may be made, based on the foregoing description, without
8 departing from the scope of the present invention, as set
9 forth in the appended claims.

CLAIMS

1 1. A method of suppressing the blast effects of
2 an explosive device upon detonation of the same comprising
3 the steps of:

4 providing a barrier which effectively encloses
5 the explosive device;

6 said barrier being spaced a predetermined dis-
7 tance from said explosive device and being of a predetermined
8 height; and

9 generating a high expansion foam and directing
0 said foam into the space between said explosive device and
1 said barrier to provide a foam barrier which surrounds said
2 explosive device and which is maintained in place by said
3 barrier whereby upon detonation of said explosive device,
4 the compression wave is suppressed by absorption thereof
5 by the foam in its path.

1 2. The method as set forth in Claim 1 wherein
2 said explosive device is completely covered by said foam
3 which extends a lateral distance greater than the vertical
4 height above said explosive device.

1 3. The method as set forth in Claim 1 wherein
2 the step of forming a barrier includes:

3 positioning at least one tubular member in
4 spaced relation to said explosive device, and
5 filling said tubular member with foam

1 4. The method as set forth in Claim 3 wherein
2 said tubular member is collapsible and wherein said foam is
3 used to inflate said tubular member and to maintain the same
4 inflated until said explosive device is detonated.

1 5. The method as set forth in Claim 3 wherein
2 said tubular member is a self-supporting member of a pre-
3 determined geometrical cross-sectional shape.

1 6. The method as set forth in any one of
2 Claims 3, 4 and 5 wherein said tubular member includes an
3 opening between the ends thereof and wherein at least a por-
4 tion of the foam within said tubular member flows through said
5 opening in order to fill at least a portion of the space be-
6 tween said explosive device and said barrier.

1 7. The method as set forth in Claim 1 wherein
2 at least a portion of said barrier is a structure in the
3 vicinity of said explosive device and wherein the step of
4 providing a barrier includes positioning at least one movable
5 barrier element in position such that said structure and said
6 barrier element cooperate to form a barrier enclosure effec-
7 tively enclosing the explosive device on all sides.

8. The method as set forth in Claim 1 wherein
said barrier includes at least two barrier elements.

9. The method as set forth in Claim 1 wherein
at least a portion of said barrier is formed of sheet material
supported in a vertical material.

10. The method as set forth in Claim 1 wherein
said barrier is of essentially the same vertical height in
all directions.

1 11. The method as set forth in Claim 1 wherein
2 said barrier includes portions of different vertical height
3 as measured with reference to the location of said explosive
4 device.

1 12. The method as set forth in Claim 1 wherein
2 said barrier includes separate barrier elements which form
3 spaced enclosures with a space therebetween, and wherein the
4 space between said barrier elements is filled with foam.

1 13. The method as set forth in Claim 12 wherein

1 14. The method as set forth in Claim 1 wherein
2 the vertical height of the foam and the radial dimension
3 thereof is sufficient to reduce the overpressure of the
4 blast wave to less than about 1 psi as measured at struc-
5 tures in the vicinity and which have a line of sight exposure
6 to the site of the explosive device.

1 15. The method as set forth in Claim 1 wherein
2 the barrier is so positioned relative to the explosive
3 device that the foam barrier extends laterally a distance
4 sufficient to reduce the overpressure of the compression
5 wave to less than about 1/2 to 1 psi as measured on the
6 side of said barrier opposite the foam enclosing side thereof.

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16. A method of suppression of the blast effects at ground level during the demolition of a structure by detonation of an explosive device, comprising the steps of:

 forming a barrier which surrounds said structure,
 said barrier being located a predetermined distance from said structure and having a predetermined height, and
 generating a high expansion foam and filling the space formed by said barrier with said foam whereby upon detonation of said explosive device the shock wave is suppressed by said foam.

17. The method as set forth in Claim 16 wherein said barrier includes spaced barrier elements one positioned inside of the other to form a containment structure surrounding said structure, and

 said foam filling said contained structure such that the foam is spaced from said structure.

1 18. A method of suppressing the blast effects
2 of an explosive device upon detonation of the same com-
3 prising the steps of:

4 providing at least one tubular barrier member
5 having an opening between the ends thereof;

6 positioning said tubular barrier member in
7 spaced relation to said explosive device;

8 flowing high expansion foam into said tubular
9 barrier member to form a foam filled barrier member, and
10 flowing high expansion foam through said tubu-
11 lar member such that the foam enters the space between said
12 tubular member and said explosive device to fill at least
13 a portion of said space to provide a fire foam barrier
14 capable of suppressing at least a portion of the compression
15 wave upon detonation of said explosive device.

1 19. A method as set forth in Claim 18 wherein
2 said tubular member is collapsible and wherein said high
3 expansion foam is used to inflate said tubular barrier member.

1 20. A method as set forth in Claim 18 wherein
2 a plurality of tubular members are positioned so as to com-
3 pletely surround said explosive device, and filling each such
4 member with said foam to form a foam filled barrier enclosure.



European Patent
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EUROPEAN SEARCH REPORT

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Application number

EP 85 10 7435

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	US-A-3 268 107 (SPERLING) * Figure 2; claim 1; column 3, lines 14-37; column 4, lines 65-75; column 5, lines 1-12 *		F 42 D 5/04
A	DE-C- 207 741 (KAISER) ---		
A	US-A-3 709 302 (STULTS) ---		
A	US-A-4 432 285 (BOYARS et al.) -----		
TECHNICAL FIELDS SEARCHED (Int. Cl.4)			
F 42 D A 62 C A 62 D			
The present search report has been drawn up for all claims			
Place of search THE HAGUE	Date of completion of the search 31-01-1986	Examiner FISCHER G.H.	
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone			
T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date			